CALIFORNIA ENERGY COMMISSION

MICROGRID RESEARCH ROADMAP

APRIL 25, 2017

NAVIGANT RESEARCH

OVERVIEW OF NAVIGANT RESEARCH TASKS

- **Identify all microgrid definitions globally**
  - Compare and contrast with DOE definition
  - Indicate overlap and congruence – as well as points of conflict
  - Note evolution of definition over time
- **California Microgrid Analysis and Case Studies**
  - Identify projects that meet the proposed CEC microgrid definition and which are or were funded by at least 50% private investment
  - Develop deep dive case studies on up to 10 microgrid projects, answering the following questions:
    - What were the primary drivers behind the project?
    - How did the sponsor determine the value of investment?
    - What metrics were used to determine to support development?
    - What was total cost (and cost $/MW)?
    - What was the business model and how was the project financed?
    - Did market participation revenue play a role in the business case analysis?
    - How many stakeholders were involved with the project?

OVERVIEW OF NAVIGANT RESEARCH TASKS (PART II)

- **North America Microgrid Analysis and Case Studies**
  - Identify projects that meet the proposed CEC microgrid definition
  - Candidate projects which were funded by at least 50% private investment will be given priority as case study candidates
  - Include projects that did receive more than 50% government funding, but which offer the prospect for repeatable deployments due to technology or business model innovation
  - Develop deep dive case studies on up to 10 microgrid projects, answering the same questions as applied to the California case study projects
- **Global Microgrid Analysis and Case Studies**
  - Identify projects that meet the proposed CEC microgrid definition
  - Candidate projects which were funded by at least 50% private investment will be given priority as case study candidates
  - Include projects that did receive more than 50% government funding, but which offer the prospect for repeatable deployments due to technology or business model innovation
  - Develop deep dive case studies on up to 10 microgrid projects, answering the same questions applied to the California and North American case study projects

OVERVIEW OF NAVIGANT RESEARCH TASKS (PART III)

- **Global Microgrid Analysis and Case Studies (continued)**
  - Analysis will focus also on broader issues impacting microgrids, noting how traditional policy tools supporting DER (i.e. net metering, FITs, tax credits and transactive energy) impact the goals of different microgrid segments and applications
  - Identify case studies that have been supported by unique or thought provoking government support that differ from projects in CA and North America
- **Value Propositions for CA, NA and Global Microgrids**
  - A matrix ranking the following value propositions will be applied to all case studies developing under this project
    - Reliability and resiliency
    - Transactive energy
    - Provision of capacity and energy services
    - Provision of ancillary services (DR, frequency regulation, etc.)
    - Reduction of carbon footprint
    - Non-electricity services (thermal energy, water, etc.)
    - Linkage to “virtual power plants” and other DER concepts.

MICROGRID DEFINITIONS: SELECTED EXAMPLES

- **U.S. Department of Energy definition:**
  - *"An integrated energy system consisting of distributed energy resources (DER) and multiple energy loads operating as a single controllable entity in parallel to or islanded from the existing power grid"*
- **U.S. Department of Defense definition:**
  - *"A DoD installation microgrid is an integrated energy system consisting of interconnected loads and energy resources which, as an integrated system, can island from the local utility grid and function as a stand-alone system."*
- **International Council on Large Electric Systems / CIGRÉ:**
  - *"Microgrids are electricity distribution systems containing loads and distributed energy resources (such as distributed generators, storage devices, or controllable loads) that can be operated in a controlled, coordinated way either while connected to the main power network or while islanded."*
- **Navigant Research definition:**

  "A microgrid is a distribution network that incorporates a variety of possible DER that can be optimized and aggregated into single system that can balance loads and generation with or without energy storage and is capable of islanding whether connected or not connected to a traditional utility power grid."

MICROGRID DEFINITIONS: SELECTED EXAMPLES (PART II)

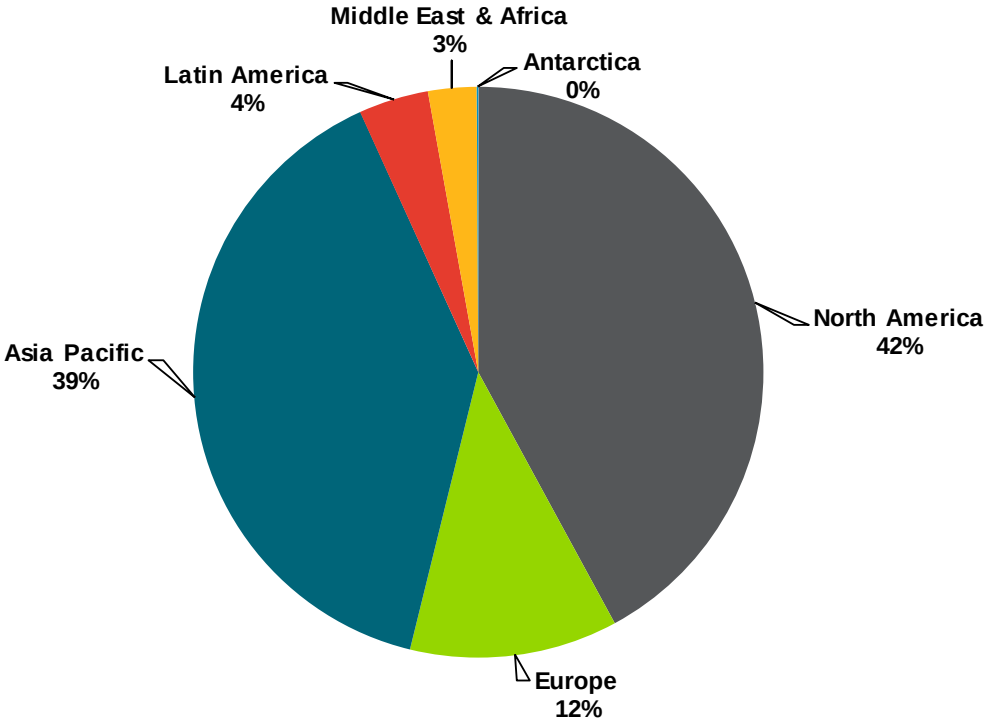
- **New York ERDA:**
  - *"Microgrids are local energy networks that are able to separate from the larger electrical grid during extreme weather events or emergencies, providing power to individual customers and crucial public services such as hospitals, first responders, and water treatment facilities."*
- **Rocky Mountain Institute:**
  - *"Small, self-balancing networks that have the ability to fractally break apart from the larger grid for autonomous operation and then seamlessly re-combine to function as part of the whole on demand. Such networks have a single point of common coupling to the grid, and include both sources of generation (such as diesel and/or gas generators, distributed solar, and distributed wind resources) as well as electrical loads that can be managed in a coordinated manner."*
- **LNBL (Chris Marnay)**
  - *"Locally controlled power system (can manage its profile with the legacy mega-grid and can also establish economic relationships with it). Can function either grid connected or as an electrical island (connect and disconnect at will)."*
  - *"Power systems or multiple ones closely co-located on sites that can function as electrical islands. Microgrids integrate different types of generation resources and manage different loads.*

FIRST CUT AT CALIFORNIA MICROGRID DATA

- **Over 120 “microgrids” identified in California**
  - These projects represent >650 MW of peak capacity
  - Just over 30% of this state portfolio is currently on-line
  - 19% of these projects are under current development
  - 41% are proposed projects
- **Most common DG source is solar PV**
  - Solar PV capacity is ~296 MW; 45% of total microgrid peak capacity
  - Energy storage capacity is ~76 MW; 11.6% of total microgrid peak capacity
- **Institutional/Campus is Largest Segment**
  - 34 projects identified
  - 185 MW or 28% of total capacity
- **Recent market activity**
  - 15 projects have come on-line since 2015
  - Most common business model is the PPA

NORTH AMERICA IS BEST OVERALL MICROGRID MARKET

Total Microgrid Power Capacity Market Share by Region, World Markets: 2Q 2016



(Source: Navigant Research)

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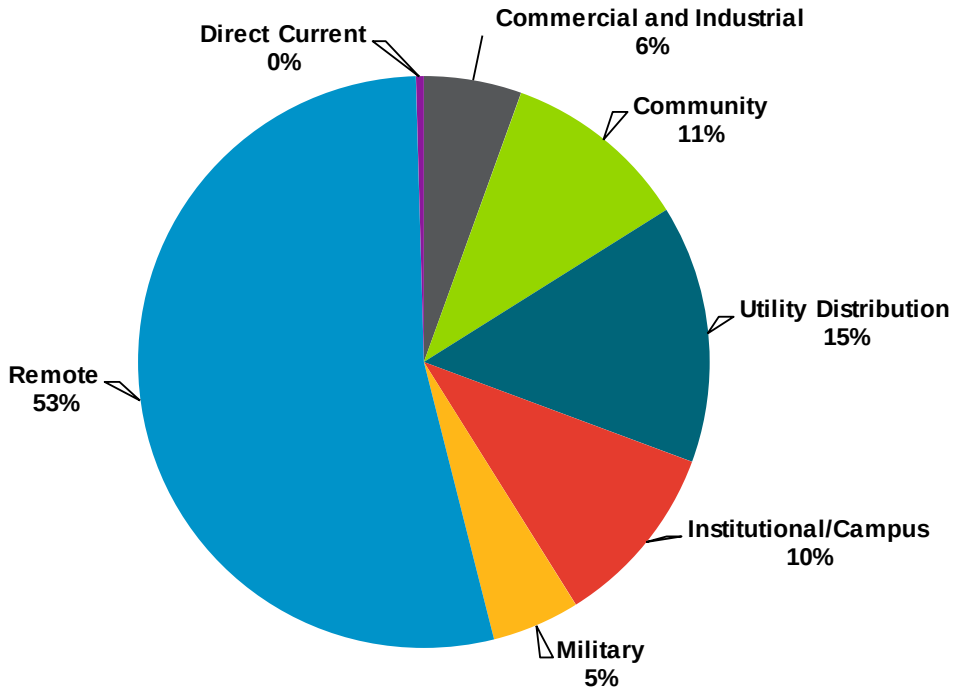
REMOTE MICROGRIDS CLEAR GLOBAL SEGMENT LEADER

Total Microgrid Power Capacity Market Share by Segment, World Markets: 2Q 2016



(Source: Navigant Research)

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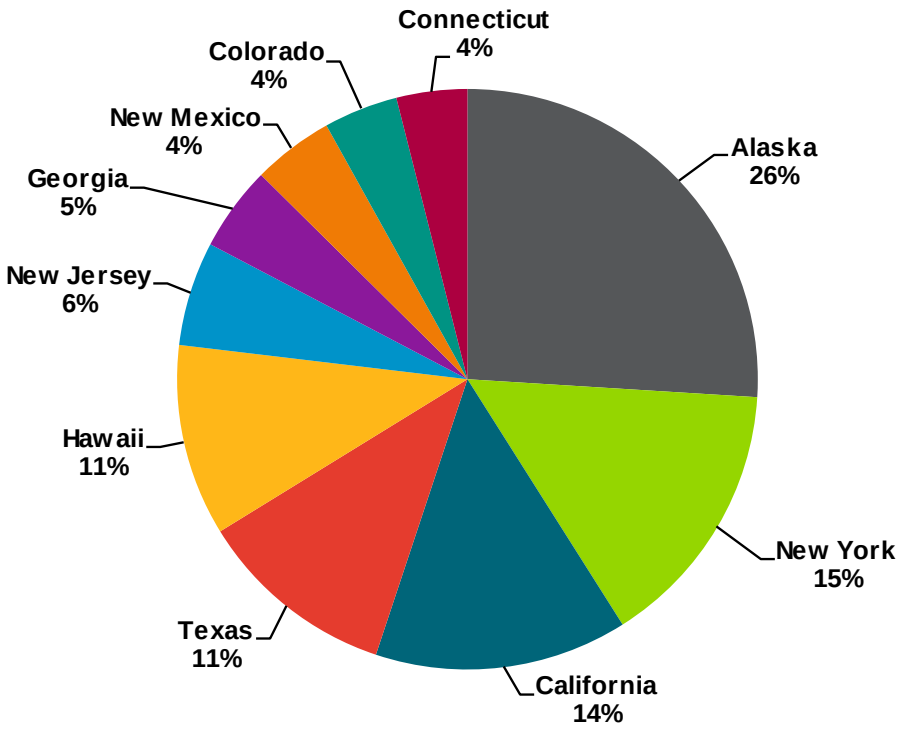
TOP US STATES BY MICROGRID CAPACITY MARKET SHARE

Share of Total Identified Microgrid Capacity, Top 10 US States: 2Q 2016

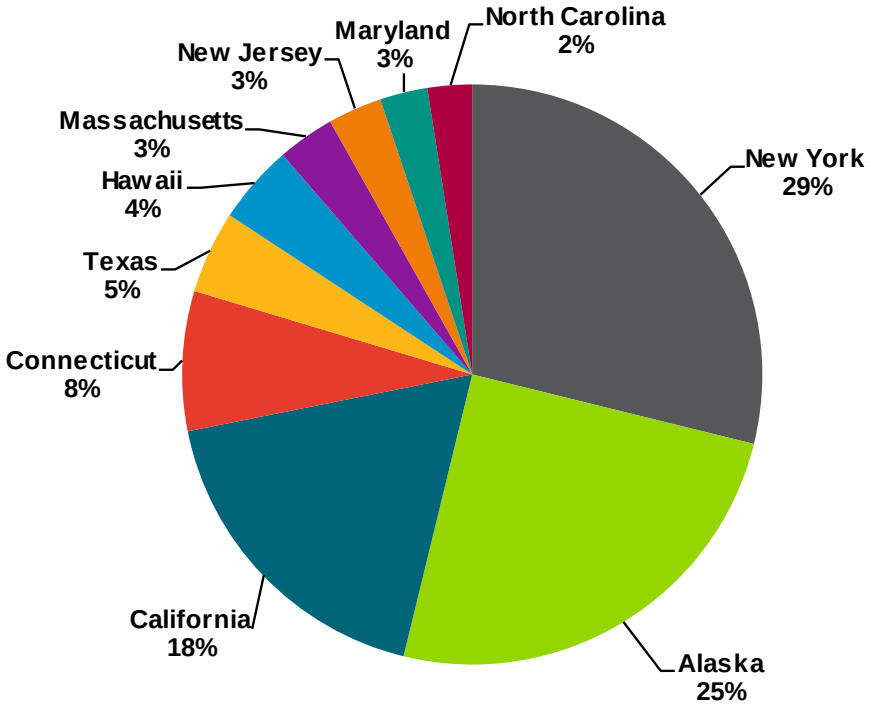


(Source: Navigant Research)

NAVIGANT RESEARCH

TOP US STATES BY TOTAL MICROGRID PROJECT NUMBER

Share of Total Identified Microgrid Projects, Top 10 US States: 2Q 2016



(Source: Navigant Research)

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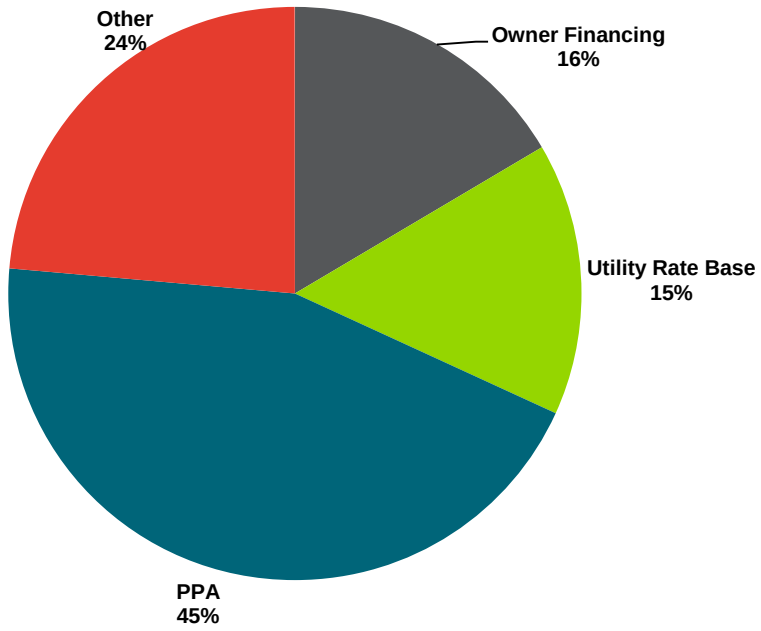
MICROGRID BUSINESS MODELS IN NORTH AMERICA

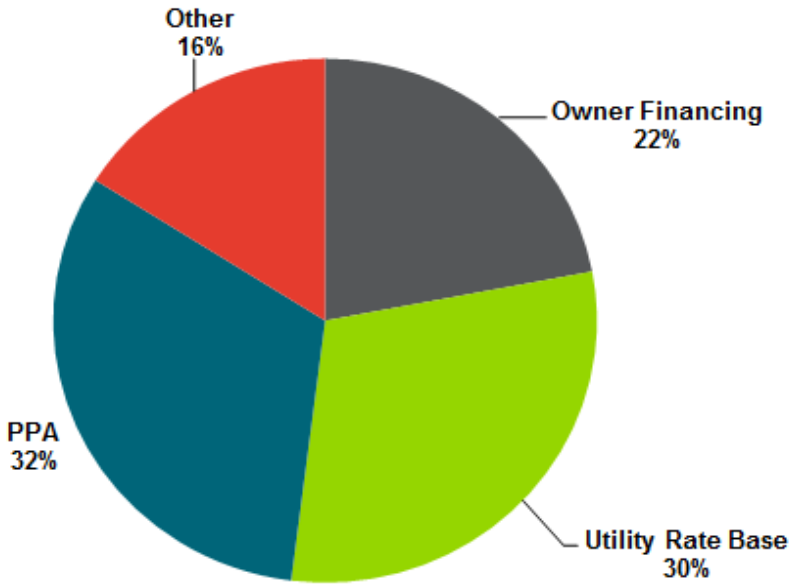
Grid-Tied, Non-Military Microgrids by Business Model Capacity, North America: 2015-2016



(Navigant Research-Hitachi)

MICROGRID BUSINESS MODELS IN N.A. BY PROJECT NUMBER

Grid-Tied, Non-Military Microgrids by Business Model Projects, North America: 2015-2016



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